VARIATION OF LIQUID TEMPERATURE NEAR A SONOLUMINESCING BUBBLE

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1 INTRODUCTION

In 1991, B.P.Barber and S.J.Putterman observed the "picosecond sonoluminescence"(PSL) from a single, stable bubble in water irradiated by the ultrasonic wave[1]. SL is the emission of light from a bubble when it collapses[2]. The pulse width of PSL is less than 50ps[1], which is the origin of the name "picosecond" sonoluminescence (PSL). Bubble's size at stable condition is determined by mass exchange of air between the interior of the bubble and its surroundings[3]. Rate of mass exchange depends on the liquid temperature at bubble wall. Thus we begin with calculations of liquid temperature at bubble wall as the first step of the prediction of bubble's size at stable condition. In order to calculate it, a simple new model of bubble dynamics is constructed including effect of non-equilibrium evaporation and condensation of water vapor at bubble wall and that of thermal conduction both inside and outside a bubble.

Calculation of liquid temperature at bubble wall is also important in the following two points. One is the possibility of high-pressure solidification of the liquid near the bubble wall suggested by R.Hickling[4]. During the final stages of collapses of a cavitation bubble, the pressure of liquid near bubble wall is in the order of 1 GPa. R.Hickling suggests that solidification of liquid takes place near bubble wall at such strong collapses by the very high pressure[4]. However, in his analysis, the latent heat of intense condensation and the thermal conduction are neglected. (At strong collapses, the intense condensation takes place because the pressure inside the bubble increases dramatically.) In the present study, the effects are taken into account, which affect $T_{L,i}$ considerably as is seen below.

The other point is the possibility of chemical reactions in liquid phase during cavitation. K.S.Suslick et al.[5] reported that the gas-temperature inside a bubble is 5200 K and that the liquid-temperature outside a bubble is 1900 K at strong collapses from the experimental determination of the first-order rate coefficients of sonochemical ligand substitution as a function of metal carbonyl vapor pressure. The result means that chemical reactions take place not only in gas-phase inside a bubble but also in liquid-phase outside a bubble. In the present study, the possibility is examined theoretically by the calculation of $T_{L,i}$.

It should be noted that the calculation of $T_{L,i}$ in the present study, taking into account the effect of the latent heat of the intense condensation at strong collapses, is the first one in the studies of SL.

2 RESULTS AND DISCUSSIONS

The model of bubble dynamics employed in the present calculation is described in ref.(6,7). Calculations are performed under a condition of the picosecond sonoluminescence(PSL). The ambient liquid temperature(T_∞) is chosen to be $20°C$. Results of the calculation are shown in fig.1-(a∼c) for three acoustic cycles. All the physical quantities of a bubble change with time periodically with the frequency of the acoustic field ($p_s(t)$) applied on the bubble. In fig.1-(c), the liquid-temperature at the bubble wall ($T_{L,i}$) is shown as a function of time. The vertical axis is the same with that in fig.1-(b). It is concluded from fig.1-(c) that $T_{L,i}$ is almost identical to T_∞

during bubble oscillations except at strong collapses. At strong collapses, $T_{L,i}$ increases to the same order of magnitude with that of the maximum temperature attained in the bubble. It is caused by the release of the latent heat by intense condensation and by the thermal conduction from the heated interior of the bubble to the surrounding liquid. At strong collapses, the intense condensation takes place because the preesure inside the bubble increases dramatically. It is concluded that the effect of the latent heat of the intense condensation should be taken into account in the calculations of $T_{L,i}$, while it has not been in the previous studies of SL. The calculated result also means that chemical reactions take place not only inside a bubble (gas-phase) but also outside a bubble (liquid-phase). The result supports the experimental conclusion by K.S.Suslick et al.[5] that liquid-phase reaction zone exists near bubble wall.

Though the liquid temperature at bubble wall ($T_{L,i}$) increases considerably at strong collapses, the possibility of the solidification suggested by R.Hickling[4] can not be excluded. Because the thickness of the heated layer is so small that low temperature region still exists outside the layer under very high pressure in the order of 1GPa.

References

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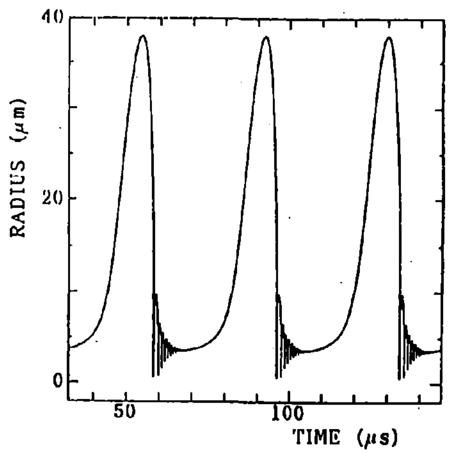
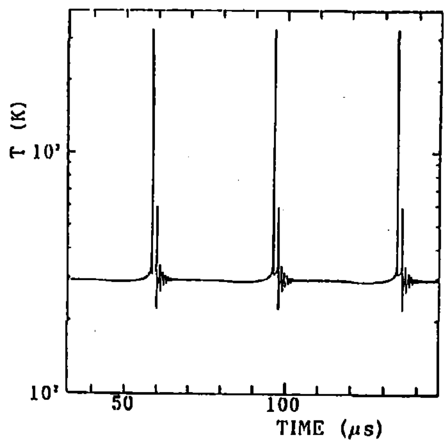
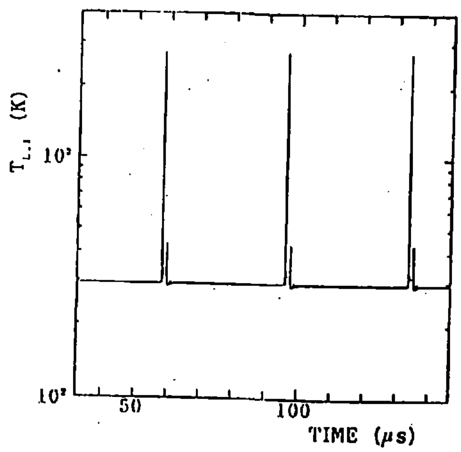


(a) The bubble radius.



(b) The temperature inside the bubble.



(c) The liquid-temperature at the bubble wall.

Fig.1 Calculated results for three acoustic cycles.